RPC Investigation Using Finely Spaced 2-D Strip Readout

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Abstract– **RPCs are in use for many high energy physics applications where there is no need for fine spatial resolution. However, there are applications such as digital calorimetry where the dimension of the induced charge at pick-up pads is of interest. Such calorimetry is proposed for eg, Particle flow calorimetrey at the ILC. While there are both experiments and calculations which address this to some extent, we have been able to read out a single gap RPC using fine pitch laser etched two-dimensional strip readout as used in GEM tracking. This measurement was made in the Fermilab test beam in conjunction with the GEM tracking test for the STAR upgrade. We discuss both data and electrostatic simulations of the signal from a single gap glass RPC.**

I. Introduction

We are interested in the geometrical size and shape of RPC, Resistive Plate Chamber, signals, in general in order to understand the detector, and more specifically because this is a promising technology for Particle Flow Calorimetry. The detector planes in a sampling calorimeter might have pixels of eg., 1 cm square. A clear understanding of the factors affecting the signal distribution might enable one to have more control over the cross-talk between pixels. The etched x and y strips for simultaneous 2D readout, as used in the test beam test of GEM, Gas Electron Multiplier, tracking [1], for STAR [2], are a good investigative tool for looking at RPC signal width. The strip readout is similar to that used at COMPASS at CERN.

In the case of a GEM detector, the actual electron avalanche is collected on the readout strips. In the case of the RPC, the signal is induced on the strips by the electric dipole field from the charge separation between avalanche electrons and the residual ions between glass plates. This RPC setup is not ideal for tracking, both because of the variation in signal amplitude for an RPC in avalanche mode, and because of the width of the induced signals from the RPC. However, this setup is a very good tool for observing the RPC signals.

In an effort to understand the signals more fully, we did some electrostatic simulations of the signal in the RPC by using the COMSOL program. In simulation we could vary parameters such as the dielectric constant of the glass, the distance of the signal pick-up strips from the resistive paint and the charge separation between the glass plates.

II. Beam Test Setup

A test of three GEM planes and one RPC plane was run in the Fermilab MT6 test beam. This is shown in Figure 3. Data were taken with a variety of beam conditions. Most of the RPC data was collected in a few hours at various times during the two week run.

The RPC was made of glass, with 1.1 mm glass plates, and 1.1 mm gap. Figure 1 shows the geometry of the RPC. The resistive coating had a resistance of more than 1 Meg-Ohm per square. The RPC we have used for these tests is run in avalanche mode. The gas used was 95% R134, 4.5% Isobutane, 0.5% SF6 for most of the testing.

The electronic readout readout chain for both RPC and GEM is as follows: The APV25 chip is used at the front end The MIT GEM controller is used for ADC and sequencing. Interfaces to data and STAR trigger-token and APV setup

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were done by Argonne National Lab on hardware from Blue-Sky electronics. The transfer to the DAQ computer is done with the CERNTech SIU and RORC developed for the ALICE experiment at CERN. The APV25-S1 chips have 128 analog channels, but we used 64 per chip in this system because of ease of making connections.

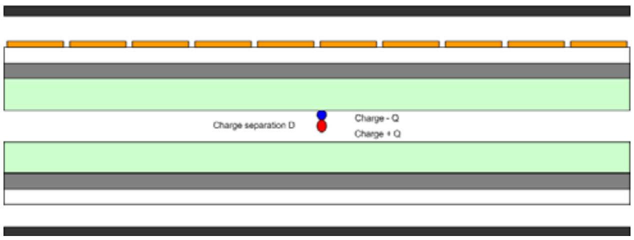

Fig. 1. Geometry which is similar to the glass RPC used in these tests. In the test and simulations, the narrower copper pickup strips were closer to the resistive paint, and the wider copper strips were 50 u further away.

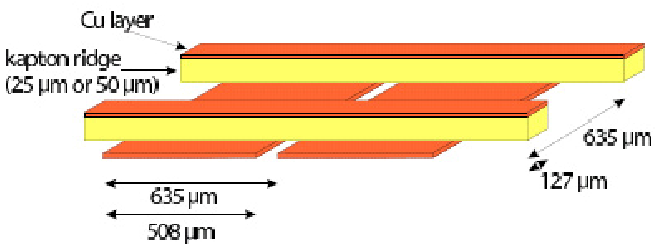

Fig. 2. Crossed strip geometry as used for both the GEM and RPC readout. Two dimensions are read out simultaneously.
In the case of a GEM detector readout using crossed strips, electrons get to both the X and Y strips after amplification in the gas. In an avalanche of eg. 2 mm wide, some are collected on the x strips, and some on the y strips. In the case of the RPC, the electrons and ions are confined to the space between glass plates, and the signal is induced in the strips by the electrostatic field. We have attempted to simulate this with a dipole electric field and a realistic geometry.

III. Measurements

An example of the data is shown in Fig. 4. The RPC signals are negative. The Y projection is shown on the left in blue. The X projection is shown on the right in pink. Some small noise at the boundaries of the three APV chips in the X view can be seen, as well as a few bad channels.

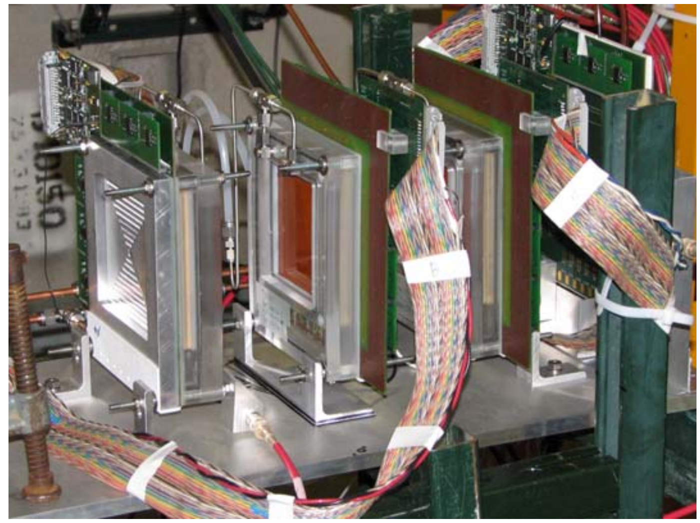

FIG. 3. Setup in Fermilab Test Beam along with a GEM tracking test. The RPC plane is at the right at the downstream end.

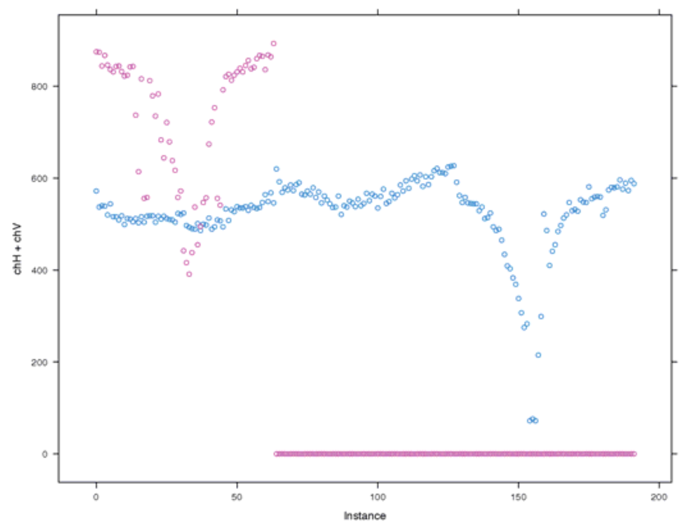

Fig. 4. An example of one event from the glass RPC as read out with strips on 635 u centers in both x and y. The Y view data is on the left in pink, and the X view data on the right in blue.

A signal shape is shown in Figure 5. Various simple functions were tried to fit the projected shape of the RPC signal. A form such as A=1/ (a * x^2 + b) was the best found so far, but appears to give a somewhat rounded peak compared to the data. There are other functional forms which have been found when simulating the signal with a single charge instead of a dipole. See Ref [3] and references therein.

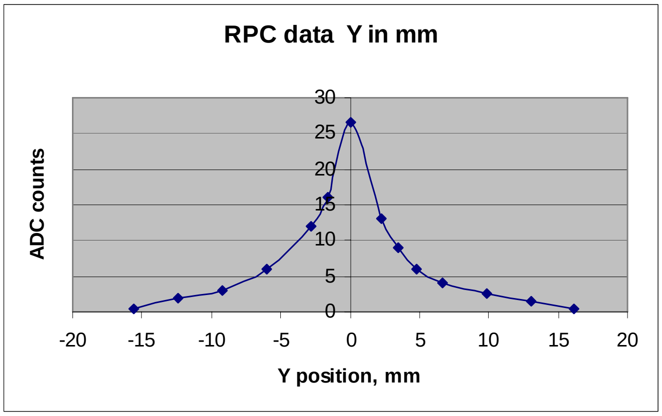

Fig. 5 A signal profile from data to be compared to simulations.

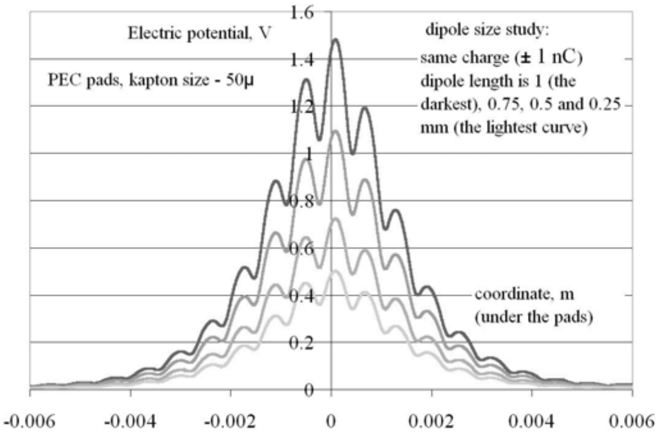

Fig. 6. Typical signal shapes from our electrostatic simulation. They are all narrower than the measured signal. This picture shows the signals from a variety of spacings of the + and – charges in the dipole.

IV. Simulations

A series of simulations was begun in order to understand which factors influenced the width of the signal distribution. We could not vary all the parameters in a beam test of the actual detector. The thickness of the glass and the dielectric constant of the glass have very large effects on signal width. This was also seen in very crude simulations which partially used the method of images.

The spacing of the positive and negative charges between the glass plates does not have a large effect on the width of the distribution seen in the signal strips. The simulations with different charge separation are shown in figure 6. This figure is the best example of simulation to be compared to data.

Figure 7 shows the geometry input and the electric field lines found in a typical simulation.

Figure 8 shows more of the details of the geometry input to the COMSOL electrostatic simulation program.

We were also concerned that the Copper strips in the detector layer farthest from the resistive paint might have an effect on the width seen in a projection at right angles to the long conductors. So far we have only been able to test this hypothesis by simulating the moving of the back layer further back do a distance larger than the strip spacing. Distances of 50, 350 and 850 microns were simulated. At this level, essentially no effect is seen on the signal width. We note that the crossed conductive strips are present in both the 2-D simulation and the actual detector.

The simulated widths are all narrower than the measured signal. Some possible reasons:
a) This is a static simulation, and the measurement is a sample after an integral over some time.
b) Dielectric constant of glass was input as 7.0, and it could be as high as 7.75 for 0 frequency.

This is a 2D simulation so far, compared with projection of 3D real signal onto strips in data. The E field calculation is static in time. The actual signals are only initially like this before currents flow in the resistive paint. We did not expect the time dependence to be a big effect because the RC time constant of paint and chamber is order several us vs shaping time of order 100 ns.

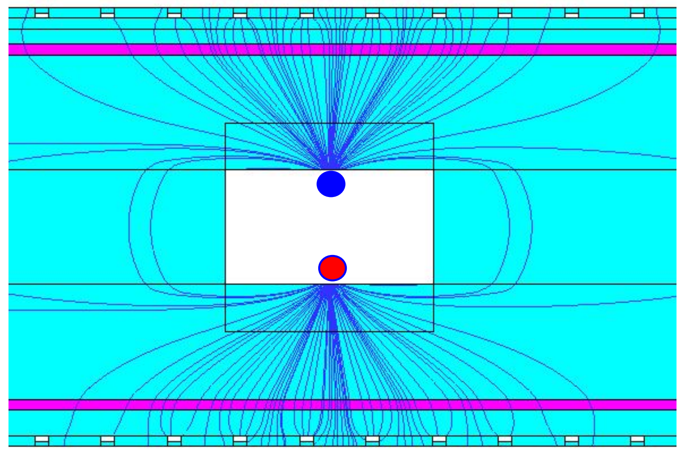

Fig. 7. Picture of Electric field lines found in the simulation. The middle horizontal band is the gas gap. The next, wide horizontal bands are the glass. The resistive paint is in violet. There are layers of mylar between the paint and the signal pickup strips. Strips are on both sides of the RPC in the simulation, but only one side in reality.

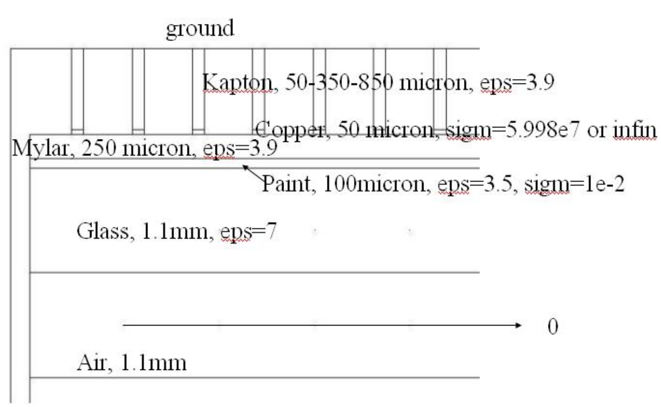

Fig. 8 Geometry input to COMSOL program for a particular simulation run. In this simulation the distance between X and Y strips was artificially increased.

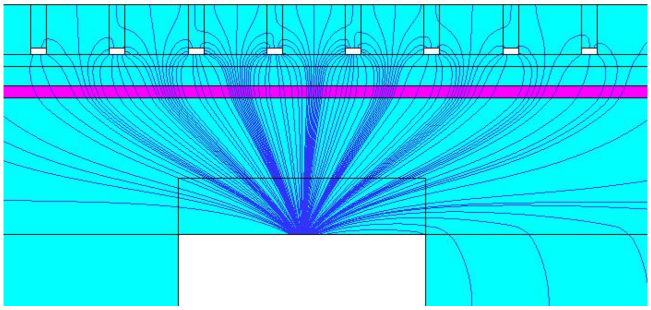

Fig. 9. The Electric field pattern with the wide back strips displaced far from the front narrow sense strips.

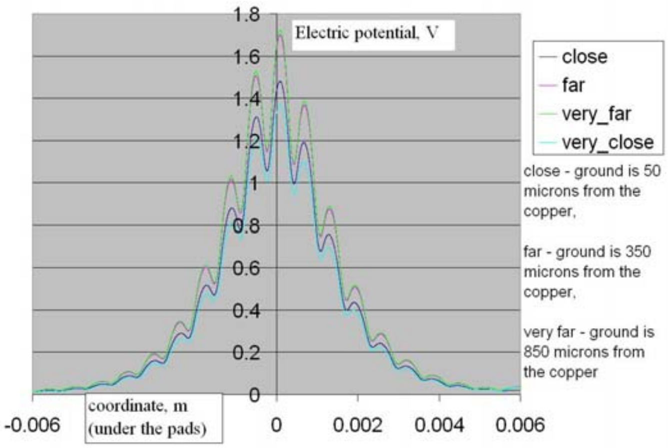

Fig 10. The z component of electric field just in front of the small readout strips for three different locations of the back transverse strips, 50 microns, 350 microns and 850 microns.

In addition to the simulations using the strip geometry used in the test beam, we did some simulations with the 1 cm sq. pad geometry proposed for use in a Particle Flow Calorimeter for the ILC.[5] One of the issues in this case is so-called cross-talk. This is measured as the fraction of events which fire two or more adjacent pads when a given threshold is used. There is extensive data on the cross talk vs threshold for such RPCs which can be compared to both our measurements and our data. Examples for analog readout from an array of 1 cm sq pixels are shown in ref [5]. One can see the number of hits above threshold for pixels at various radii from the pixel with the highest amplitude. There are also measurements of overall multiplicity for and for so-called digital readout of such pixels in ref [6]. It is claimed in both cases that the multiplicity can be simulated with random hits of a black disk, where the disk corresponds to the part of the amplitude vs radius function above threshold. Our projected measurements and simulations should correspond the projections of this function.

In Figure 11 and 12 we show the cases corresponding to a track through the center of a pad or to a track going between pads. These simulations were done for several different cases of the ground plane behind the signal pads. There is some significant difference in the observed signals, depending on the distance of the ground plane (capacitive coupling to the pads) and on the resistance of the ground plane. In particular, as seen in Figure 13, the cases simulated with perfectly conducting ground plane have much less negative overshoot at the edges of the signal.

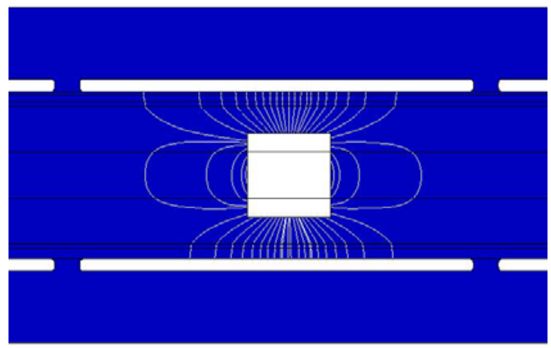

Fig. 11. The geometry and simulated electric field for an RPC with 1 cm signal pick-up pads. In this case the event is near the center of a pad.

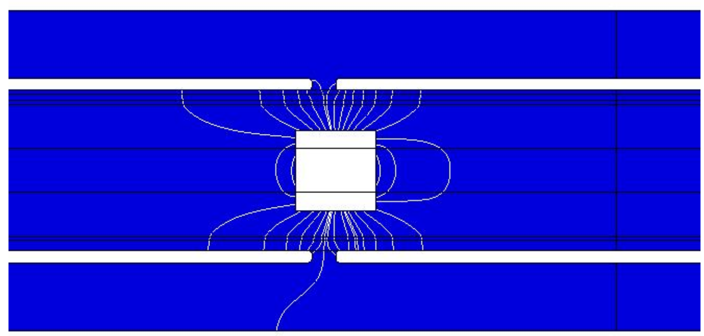

Fig. 12. The geometry and simulated electric field for an RPC with 1 cm signal pick-up pads. In this case the event is near the boundary between two pads.

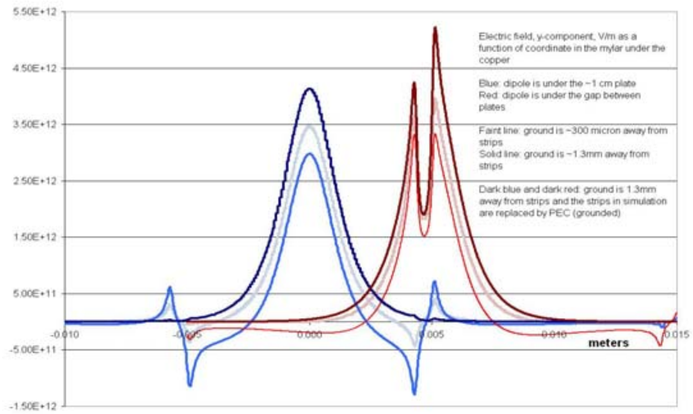

Fig. 13. The z component of electric field between the copper pads and the insulating mylar which is over the resistive paint. This is shown for simulations of two locations of the dipole event, and for 3 different ground planes behind the pick-up pads.The dark blue and dark red (highest peaks) are for a perfect conductor ground 1.3 mm behind the pads. The faint line is for 300 u behind, and thin copper conductor. The bottom solid lines are for the ground 1.3 mm behind and thin copper conductor.

V. Conclusions

We have measured the shape of RPC signals in a Glass RPC with 1.1 mm glass and 1.1 mm gap. This measurement can be compared to other kinds of measurements and to simulations. Our simulated widths are narrower than the measured signal. This could be because: a) This is a static simulation, and the measurement is a sample after an integral over some time. b) Dielectric constant of glass was input as 7.0, and it could be as high as 7.75, or c) There is possibly some other factor which could not be simulated in the time available. We hope to do more extensive simulations in the future. Both simulations and our data can be compared to other types of measurements such as pad multiplicity for RPCs to be used in Particle Flow Calorimeters.

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References

[1] F. Simon, J. Kelsey, M. Kohl, R. Majka, M. Plesko, D. Underwood, T. Sakuma, N. Smirnov, H. Spinka and B. Surrow, “Triple-GEM Detectors for the Forward Tracker in STAR”, this conference N12-3
[2] K. H. Ackermann et al, “STAR detector overview,” Nucl. Instrum. Meth., vol. A499, pp. 624-632, 2003.
[3] C. Lu, “Induced Signal in RPC”, Princeton, SNIC Symposium, Stanford, CA, April 2006, www.slac.stanford.edu/econf/C0604032/ papers/0201.PDF
[4] V. Ammosov, et al, “Multi-Strip Readout in RPCs: Cross-Talk and Cluster Size”, Protvino, IHEP 99-52
[5] G. Drake, J. Repond, D. Underwood, L. Xia, "Resistive Plate Chambers for hadron calorimetry: Tests with analog readout." (Argonne National Lab) Nucl.Instrum.Meth.A578:88-97,2007
[6] Lei Xia, “Resistive Plate Chamber as an Active Medium for a Digital Hadron Calorimeter”, 2005 International Collider Workshop, http://www.slac.stanford.edu/econf/C050318/papers/0921.PDF